Product Qualification Program

Final Hail Stress Sequence Report 35 mm

Aiko Solar

AIKO-A645-GRH66Dw
BOM 1

Report Number: R9530E-1

Date: 21 January 2025

Kiwa PVEL

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We Create Trust

Report details

Report no.	R9530E-1	Customer	Shenzhen Aiko Digital Energy Technology Co., Ltd.
Project no.	9530	Customer Contact	Su Xiong
Date of issue	21 January 2025		

Approval

	Name	Title	Signature
Preparation	Charan Gurram	Report Writer	
Verification	Jeff Cleland	Project Manager	
Approval	Jean-Nicolas Jaubert	Director of Operations, China	

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Revision	Date	Reason for Issue	Preparation	Verification	Approval
1	1/21/2025	Initial Release	Charan Gurram	Jeff Cleland	Jean-Nicolas Jaubert

The test results in this report relate just to the test objects.

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1. Summary

Aiko Solar (Shenzhen Aiko Digital Energy Technology Co., Ltd.) submitted AIKO-A645-GRH66Dw photovoltaic (PV) modules for accelerated stress testing and characterization under PVEL LLC's (Kiwa PVEL) Product Qualification Program (PQP). All testing in this report was completed at Kiwa PVEL's lab in Jiangsu, China. Real-world failure mechanisms outlined in Appendix C are simulated in a controlled laboratory environment, and state-of-the-art module characterization techniques are utilized to measure the performance of the modules as they progress through the protocol. The results of the PQP testing are presented in this report.

This report is part of Kiwa PVEL's PQP project 9530. Please refer to Appendices A and B for more details. BOM information can be found in report R9530A.

1. 1. Manufacturer specifications

The module specifications were taken from the datasheet provided by the customer. The datasheet can be found in Appendix F.

AIKO-A645-GRH66Dw Datasheet Specifications						
Model	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	645	49.20	41.90	16.55	15.40	79.24

1. 2. Test data summary

Average Post-stress Change in P_{MAX} Relative to Initial Measurement [%]	
Model	HSS Post-Hail
AIKO-A645-GRH66Dw	-0.24
Visual Inspection Findings[1]	
AIKO-A645-GRH66Dw	None
Wet Leakage Insulation Resistance Meets IEC 61215-1:2021 Requirements[2]	
AIKO-A645-GRH66Dw	Yes
Electrical Circuitry[3]	
AIKO-A645-GRH66Dw	Pass

[1] Major visual defects, if present, are defined as such by IEC 61215-1:2021.
[2] For reference, IEC 61215-2:2021 MQT 15 defines a passing insulation resistance for the type of module tested to be no less than 40 MΩ·m²
[3] Electrical circuitry failures encompass samples exhibiting an open-circuit during or post-test, as well as bypass diode failure (as recorded in the bypass diode functionality test after the thermal cycling and mechanical stress sequences or as detected in EL pictures after other test sequences).

2. Hail Stress Sequence

As the global climate changes and PV deployment increases to a variety of locations around the world, PV modules mounted in the field may be exposed to severe hail impacts beyond what is covered by the IEC 61215 baseline hail test. These hail impacts can result in broken glass and/or cracked cells, and those cracked cells can eventually lead to power loss for hail damaged modules. Kiwa PVEL's HSS test is focused on determining a module's susceptibility to these hail impact failure modes.

The test sequence starts when test samples are struck by a 35±1.8 mm / 20.7±1.0 g lab-manufactured ice ball at terminal velocity 27.2±1.4 m/s in 11 different locations normal to the module as indicated by IEC 61215-2:2021 MQT 17. These hail strikes deliver a nominal impact energy of 7.7 joules.

Shot No.	Module Location
1	Any corner of the module window, not more than one radius of ice-ball from the module edge.
2	Any edge of the module, not more than one radius of ice-ball from the module edge.
3, 4	Over the circuit near interconnects (i.e., cell interconnects and bus ribbons).
5, 6	Over edges of the circuit (e.g., individual cells).
7, 8	On the module window, not more than half diameter of ice ball from one of the points at which the module is mounted to the supporting structure.
9, 10	On the module window, at points farthest from the points selected above.
11	Any points which may prove especially vulnerable to hail impact like over the junction box.

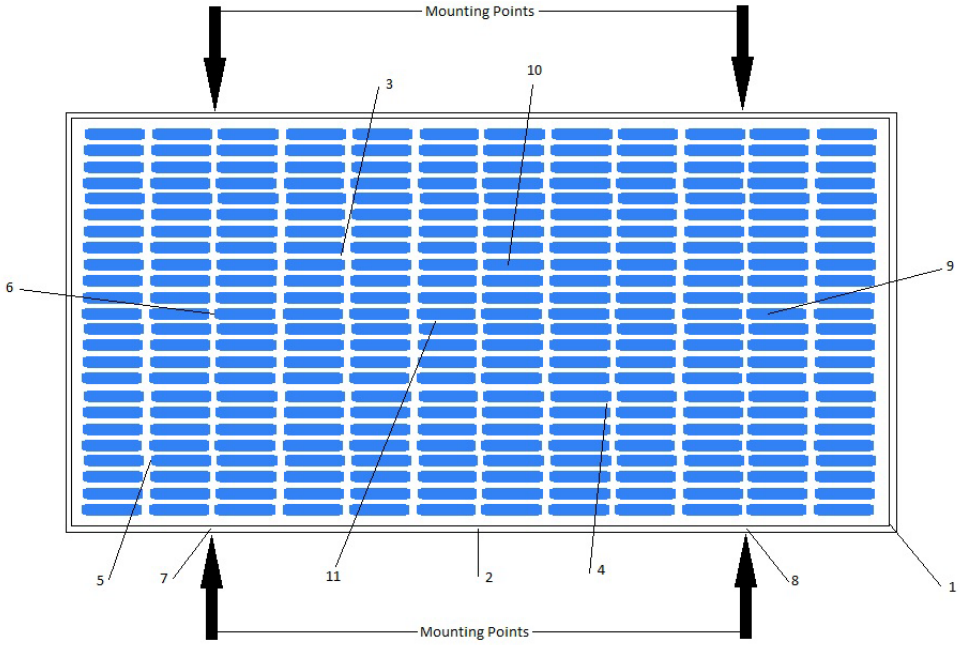


Figure 2-1: Location of 11 hail strikes.

The actual hail diameter, mass, velocity and impact locations achieved during testing were all within the allowable tolerances specified in IEC 61215-2:2021 MQT 17.

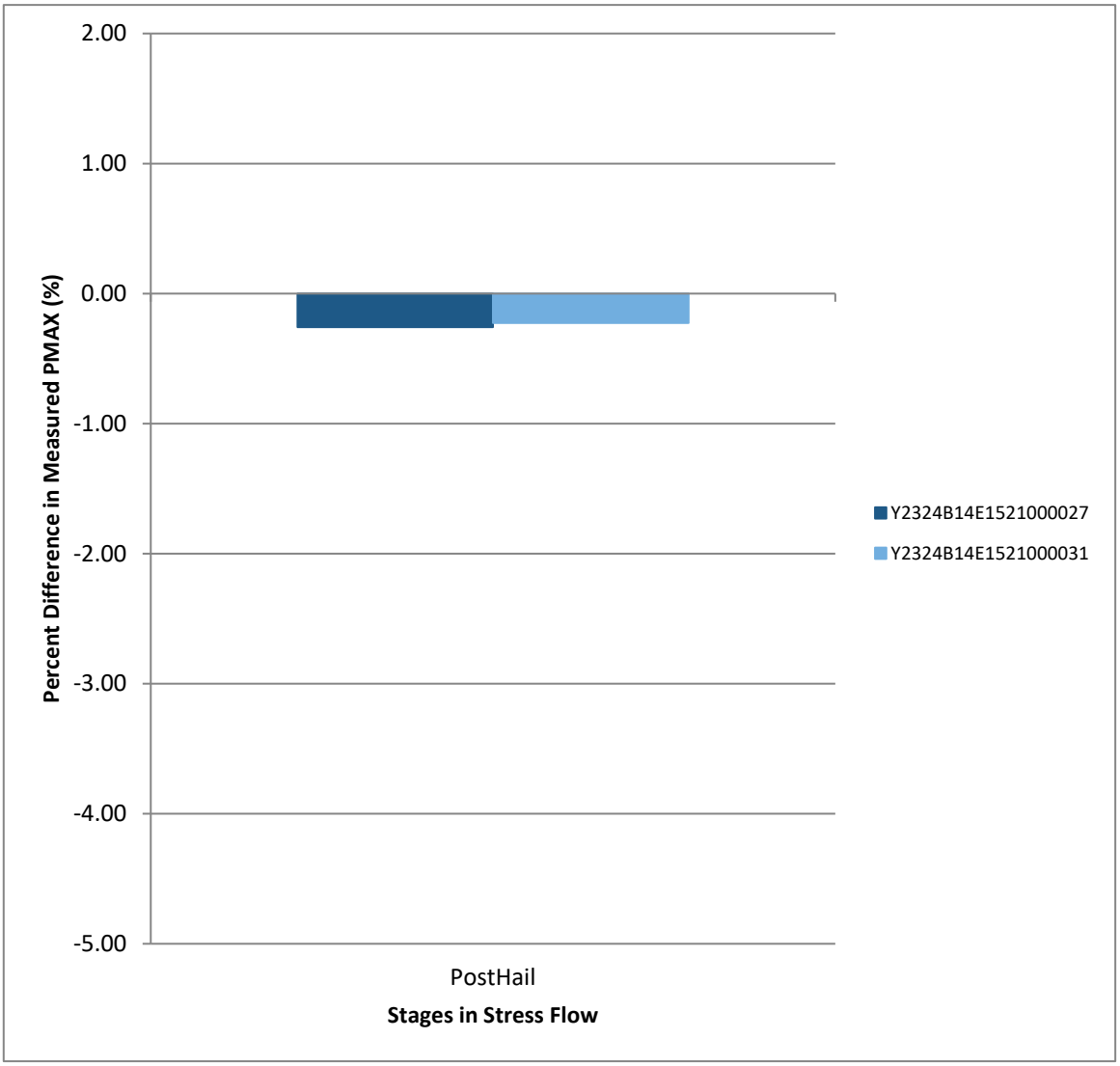


Figure 2-2 Percent deviation in measured P_{MAX} due to stress

2. 1. Front side STC performance test data - HSS

Pre-stress Test Data							
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	635.1	49.11	42.14	15.96	15.07	81.01
AIKO-A645-GRH66Dw	Y2324B14E1521000031	634.8	49.11	42.16	15.92	15.06	81.18

Post-Hail Test Data							
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	633.5	49.03	42.15	15.97	15.03	80.90
AIKO-A645-GRH66Dw	Y2324B14E1521000031	633.3	49.04	41.96	15.96	15.09	80.92
Percent Deviation from Pre-stress Test Data							
Model	Serial Number	P_{MAX} [%]	V_{OC} [%]	V_{MP} [%]	I_{SC} [%]	I_{MP} [%]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	-0.26	-0.16	0.02	0.04	-0.28	-0.13
AIKO-A645-GRH66Dw	Y2324B14E1521000031	-0.23	-0.14	-0.47	0.24	0.25	-0.32

2. 2. Rear side STC performance test data - HSS

Pre-stress Test Data							
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	440.7	48.63	41.61	11.08	10.59	81.75
AIKO-A645-GRH66Dw	Y2324B14E1521000031	439.8	48.64	41.28	11.09	10.65	81.52

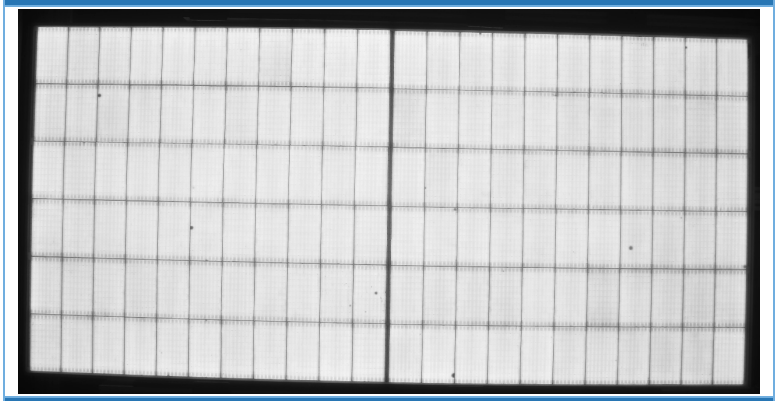
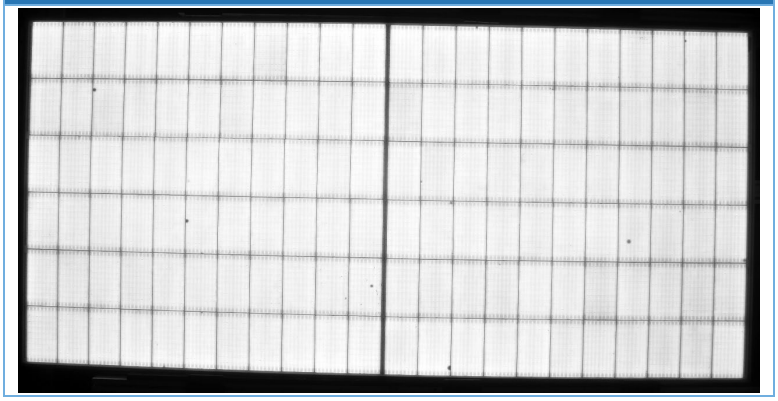
Post-Hail Test Data							
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	439.4	48.53	41.32	11.08	10.63	81.67
AIKO-A645-GRH66Dw	Y2324B14E1521000031	438.6	48.54	41.33	11.07	10.61	81.63
Percent Deviation from Pre-stress Test Data							
Model	Serial Number	P_{MAX} [%]	V_{OC} [%]	V_{MP} [%]	I_{SC} [%]	I_{MP} [%]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	-0.30	-0.19	-0.71	-0.01	0.42	-0.10
AIKO-A645-GRH66Dw	Y2324B14E1521000031	-0.27	-0.21	0.11	-0.19	-0.38	0.13

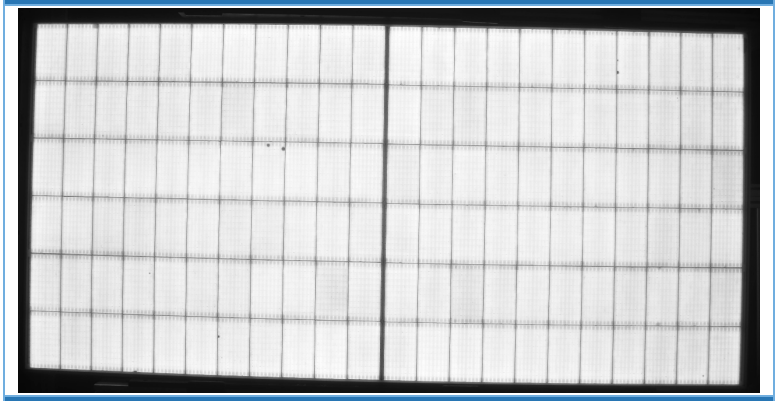
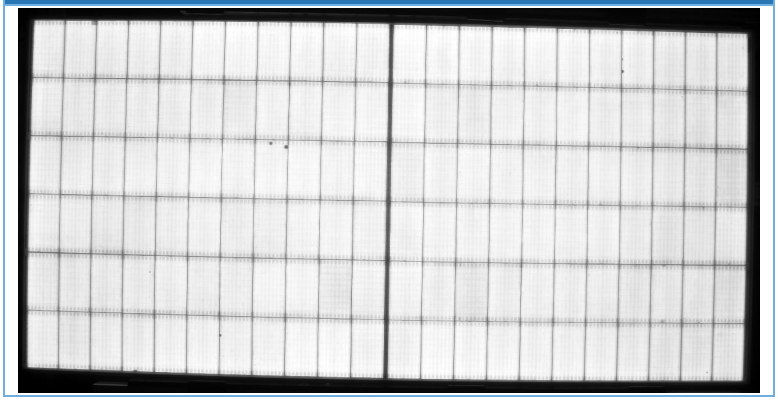
2. 3. Front side 200 W/m² performance test data - HSS

Pre-stress Test Data							
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	118.1	46.62	40.27	3.16	2.93	80.13
AIKO-A645-GRH66Dw	Y2324B14E1521000031	117.8	46.63	40.15	3.16	2.94	80.05

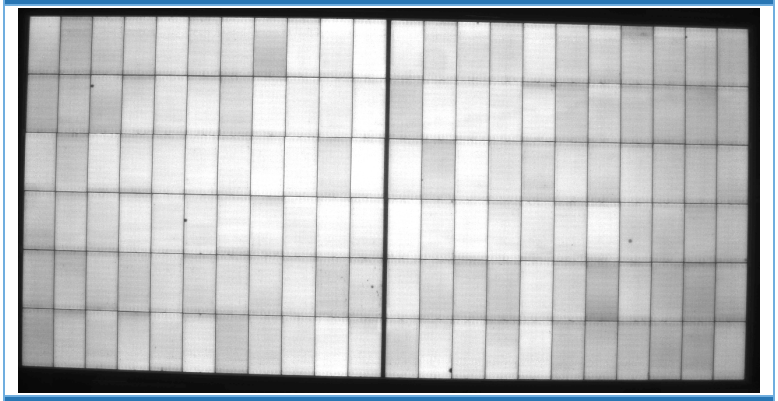
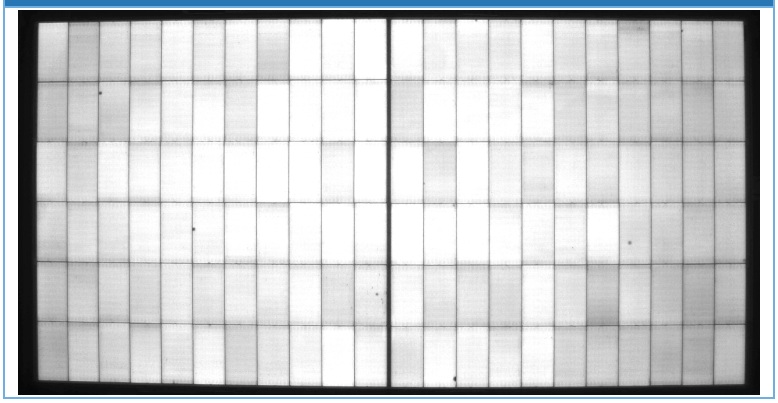
Post-Hail Test Data							
Model	Serial Number	P_{MAX} [W]	V_{OC} [V]	V_{MP} [V]	I_{SC} [A]	I_{MP} [A]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	118.5	46.59	40.24	3.18	2.95	79.99
AIKO-A645-GRH66Dw	Y2324B14E1521000031	118.4	46.59	40.10	3.18	2.95	79.97
Percent Deviation from Pre-stress Test Data							
Model	Serial Number	P_{MAX} [%]	V_{OC} [%]	V_{MP} [%]	I_{SC} [%]	I_{MP} [%]	FF [%]
AIKO-A645-GRH66Dw	Y2324B14E1521000027	0.34	-0.07	-0.08	0.58	0.42	-0.17
AIKO-A645-GRH66Dw	Y2324B14E1521000031	0.46	-0.08	-0.11	0.64	0.58	-0.10

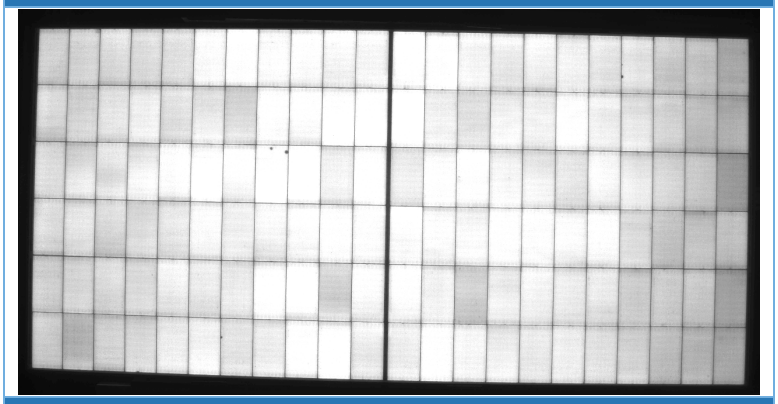
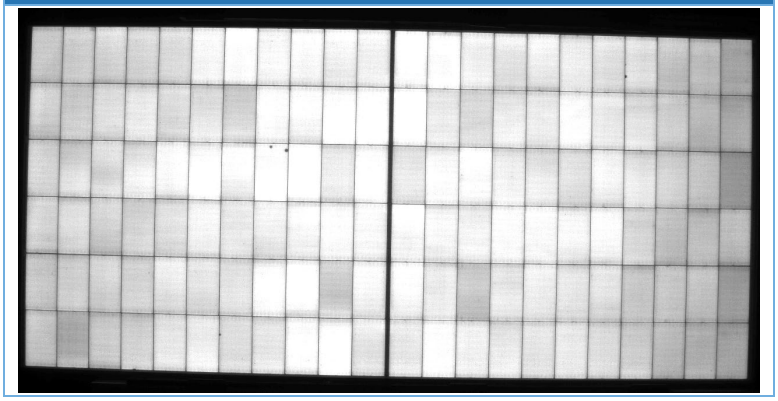
2. 4. 1.0 * I_{SC} Electroluminescence images – HSS

Model: AIKO-A645-GRH66Dw Serial Number: Y2324B14E1521000027
Pre-stress

Post-Hail Test


Model: AIKO-A645-GRH66Dw Serial Number: Y2324B14E1521000031
Pre-stress

Post-Hail Test


2. 5. 0.1 * I_{SC} Electroluminescence images - HSS

Model: AIKO-A645-GRH66Dw Serial Number: Y2324B14E1521000027
Pre-stress

Post-Hail Test


Model: AIKO-A645-GRH66Dw Serial Number: Y2324B14E1521000031
Pre-stress

Post-Hail Test


2. 6. Visual inspection notes – HSS

Pre-stress Inspection Notes				
Model	**Serial Number**	**Notes**	**Defect Category**	**Photo**
AIKO-A645-GRH66Dw	Y2324B14E1521000027	Not Applicable	None	Not Applicable
AIKO-A645-GRH66Dw	Y2324B14E1521000031	Not Applicable	None	Not Applicable

Post-Hail Test Inspection Notes				
Model	**Serial Number**	**Notes**	**Defect Category**	**Photo**
AIKO-A645-GRH66Dw	Y2324B14E1521000027	Not Applicable	None	Not Applicable
AIKO-A645-GRH66Dw	Y2324B14E1521000031	Not Applicable	None	Not Applicable

2. 7. Wet leakage current test data – HSS

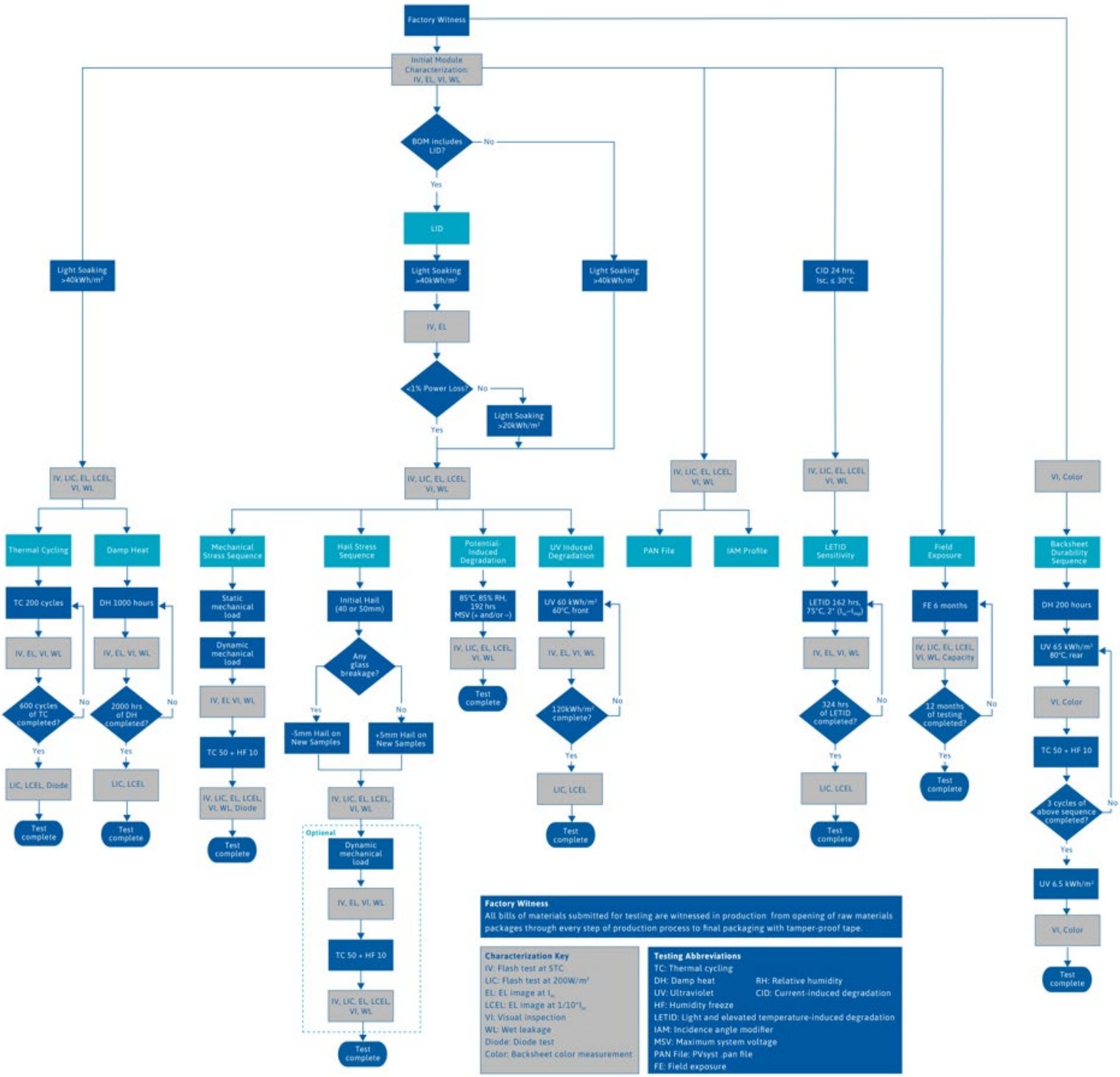
Pre-stress Test Data			
Model	**Serial Number**	**Insulation Resistance [MΩ·m²]**	**Within IEC 61215's Requirement**
AIKO-A645-GRH66Dw	Y2324B14E1521000027	19259	Yes
AIKO-A645-GRH66Dw	Y2324B14E1521000031	17477	Yes

Post-Hail Test Data			
Model	**Serial Number**	**Insulation Resistance [MΩ·m²]**	**Within IEC 61215's Requirement**
AIKO-A645-GRH66Dw	Y2324B14E1521000027	18908	Yes
AIKO-A645-GRH66Dw	Y2324B14E1521000031	18314	Yes

Exhibit A – BOM Details

PI Berlin witnessed the production of the modules tested in this report and verified the BOM components. BOM information can be found in Kiwa PVEL Report R9530A.

Appendix A – Product Qualification Program (PQP)



Appendix B – List of Reports

The following is a list of all reports issued over the duration of an entire module PQP.

- Witness Report
- Intake Report
- Light-induced Degradation Report
- Hail Stress Sequence Report
- Interim Reliability Report
- Final Reliability Report
- Interim Backsheet Durability Report (not required for glass//glass modules)
- Final Backsheet Durability Report (not required for glass//glass modules)
- Optional: PAN File Parameter Measurement Report
- Optional: Incidence Angle Modifier Report
- Optional: Interim Field Exposure Report
- Optional: Final Field Exposure Report

Appendix C – Typical PV Module Failure Mechanisms

	Light induced Degradation	Light and Elevated Temperature Induced Degradation	Thermal Cycling	Damp Heat	Backsheet Durability Sequence	Mechanical Stress Sequence	Hail Stress Sequence	Potential-Induced Degradation (PID)
Corrosion of cell metallization				✓		✓	✓	
Junction box failure (solder joints, arcing, etc.)			✓			✓	✓	
Glass fracture						✓	✓	
Bypass diode failure (short or open)			✓	✓		✓	✓	
Cracked cells			✓			✓	✓	
Solder joint degradation			✓			✓	✓	
Delamination				✓	✓			
Junction box detach				✓				
Connector embrittlement (moisture ingress)			✓	✓	✓			
Frame tape or frame adhesive failure						✓		
Frame fatigue						✓		
Optical degradation of encapsulant and backsheet					✓			
Light-Induced Degradation (LID)	✓							
Light and Elevated Temperature Induced Degradation (LETID)		✓						
Outgassing of in-laminate materials (Chemical incompatibilities)			✓	✓	✓	✓	✓	
Backsheet embrittlement leading to cracks			✓	✓		✓	✓	
Busbar sharp edges, solder peaks, cutting through backsheet			✓					
Electrochemical corrosion of busbars or cell metallization								✓
Ion migration / Polarization / Potential-Induced Degradation (PID)								✓
Discoloration of frame, junction box, or polymeric materials				✓	✓	✓	✓	
Backsheet stack layer delamination				✓		✓	✓	
Hail damage							✓	

Appendix D – Flash-Test Measurement Summary

HALM CetisPV-Moduletest3 pulsed solar simulator (flash-tester)

- Class A+A+A+
  - Non-uniformity of irradiance ≤ 1%
  - Long-term pulse instability ≤ 1%
  - Spectral irradiance distribution ≤ ± 12.5%
- All performance values are extracted from the measured I-V data
- Expanded (k = 2) uncertainty values at STC (assuming a spectral mismatch factor of 1 and not including module metastability behavior):
  - I_{SC}: ± 2.0%
  - V_{OC}: ± 0.8%
  - P_{MAX}: ± 2.1%
- Maximum deviation of achieved temperature/irradiance from target temperature/irradiance:
  - Temperature: ± 1°C
  - Irradiance: ± 0.5%

PI's HALM CetisPV-Moduletest3 pulsed solar simulator was calibrated using the reference module listed below.

Tested Device Technology	Reference Module Identifier	Reference Module Technology	Calibration Laboratory	Next Calibration Due Date
p-type crystalline-Si PERC	L01220710300014	p-type crystalline-Si PERC	Fraunhofer ISE	August 7, 2026

After calibrating the flash-tester to the reference module, the modules were flash-tested following the guidance of IEC 60904-1:2020.

Appendix E – List of Abbreviations

Abbreviation	Meaning
BOM	Bill of Material
BSF	Back Surface Field
CdTe	Cadmium Telluride
Kiwa PVEL	Kiwa PVEL LLC
EL	Electroluminescence
HJT	Heterojunction
IEC	International Electrotechnical Commission
IBC	Interdigitated Back Contact
I_{MP}	Current at maximum power
I_{SC}	Short-circuit current
PERC	Passivated Emitter and Rear Contact
P_{MAX}	Maximum power
PQP	Product Qualification Program
PV	Photovoltaic
STC	Standard test conditions
V_{MP}	Voltage at maximum power
V_{OC}	Open-circuit voltage

Appendix F – Manufacturer Datasheet

The manufacturer's datasheet(s) are included on the following pages.

AIKO

STELLAR

1N+66 Dual-Glass Module

635W-665W

Technical Features:

- Partial Shading Optimisation
- Better Temperature Coefficient
- High Temperature Restriction
- Micro-crack Resistance
- Higher Power
- Lower BOS
- More Aesthetic Values

ESG AWARD 2023/24

inter solar award 2023 WINNER

reddot winner 2023

15 year Product Warranty

30 year Performance Warranty

CE

TÜVRheinland

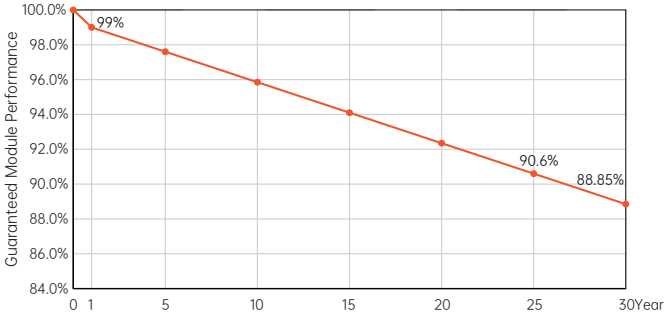
Munich RE

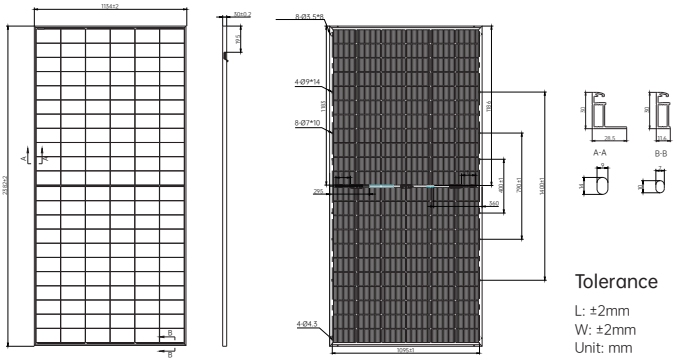
Stellar 1N+66

AIKO-A-GRH66Dw

665W	24.6%	⩽1%	⩽0.35%
Output	Efficiency	First-year Degradation	Annual Degradation from Year 2-30

30-year Linear Performance Warranty





Tolerance

L: ±2mm
W: ±2mm
Unit: mm

Electrical Characteristics (STC: AM1.5 1000W/m² 25℃ NOCT: AM1.5 800W/m² 20℃ 1m/s)

Power Tolerance:0~ + 3%

Module Type	AIKO-A635-GRH66Dw		AIKO-A640-GRH66Dw		AIKO-A645-GRH66Dw		AIKO-A650-GRH66Dw		AIKO-A655-GRH66Dw		AIKO-A660-GRH66Dw		AIKO-A665-GRH66Dw	
Test Conditions	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT	STC	NOCT
P_{max} [W]	635	481	640	485	645	489	650	493	655	496	660	500	665	504
V_{oc} [V]	49.00	46.49	49.10	46.58	49.20	46.68	49.30	46.77	49.40	46.87	49.50	46.96	49.60	47.06
V_{mp} [V]	41.70	39.56	41.80	39.66	41.90	39.75	42.00	39.85	42.10	39.94	42.20	40.04	42.30	40.13
I_{sc} [A]	16.41	13.26	16.48	13.32	16.55	13.37	16.62	13.43	16.69	13.49	16.76	13.54	16.83	13.60
I_{mp} [A]	15.23	12.18	15.32	12.24	15.40	12.31	15.48	12.38	15.56	12.44	15.65	12.51	15.73	12.57
Module Efficiency	**23.5%**		**23.7%**		**23.9%**		**24.1%**		**24.2%**		**24.4%**		**24.6%**	

Mechanical Specification

Bifacial Factor	70±5%
Cell Type	N-Type ABC
Glass	Dual glass,2.0+2.0mm coated semi-tempered glass
Frame	Anodized aluminum
Cable	4mm²(IEC) 12AWG(UL) +350mm, -280mm/±1400mm or Customized Length
No. of Cells	132(6*22)
Junction Box	IP68, 3 bypass diodes
Connector	MC4 compatible/MC4-Evo2
Weight	33.5kg±3%
Dimension	2382*1134*30mm
Package Detail	36pcs per pallet / 144pcs per 20'GP / 720pcs per 40'HC

Temperature Ratings (STC)

Temperature Coefficient of I_{sc}	+ 0.05%/ ℃
Temperature Coefficient of V_{oc}	- 0.22%/ ℃
Temperature Coefficient of P_{max}	- 0.26%/ ℃

Installation Guide

Operation Temperature	-40℃ - +85℃
Maximum Series Fuse Rating	30A
Protection Class	Class II
V_{oc} and I_{sc} Tolerance	±3%
Maximum System Voltage	DC1500V
Maximum Static Loading	Front 5400Pa Back 2400Pa
Hail Test	25 mm diameter hail at 23 m/s
Fire Rating	IEC Class C

www.aikosolar.com
marketing@aikosolar.com

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